

GIANO: user manual for cryogenic instrument and controls

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1.1	Sep 8 th 2013	All	Added figures with screen-shots of PLC panel
1.2	Oct 17 th 2013	2.1,2.3, 3.7	Added: - turbo-valve to be protected/dismounted - heaters disconnected - extended list of alarms
1.3	Oct 18 th 2013	3.2,3.3,3.4	Added: - infos on delay times after pumps-off - details on pressure control parameters - constraints on cooling speed
1.4	Oct 19 th 2013	3.4	- updated list of alarms

Reference documents

RD1	Gennari et al. 2006, “The spectrometer optics of GIANO-TNG”, SPIE 6269-127
RD2	Gennari et al. 2006, “The mechanics and cryogenics of GIANO-TNG”, SPIE 6269-128
RD3	Mochi et al. 2008, “Performances of the cryogenic system of GIANO-TNG”, SPIE 7014-125
RD4	Origlia & Oliva 2012, “Pre-commissioning report version 2”, dated 23 April 2012
RD5	Baffa et al. 2006, “The versatile acquisition system of GIANO”, SPIE 6274-25
RD6	Oliva et al. 2012, “Performances and results of the detector acquisition system of GIANO-TNG”, SPIE 8453-103
RD7	Baffa & Giani 2011, “Il programma di telemetria lillend, l’interfaccia web”, Arcetri Technical Report 7/2011
RD8	Biliotti 2012, “Elettronica di acquisizione di GIANO, descrizione di insieme”, Arcetri Technical Report 6/2012
RD9	Biliotti et al. 2012, “Elettronica di acquisizione di GIANO, interfaccia digitale”, Arcetri Technical Report 8/2012
RD10	Biliotti 2012, “Elettronica di acquisizione di GIANO, parte analogica a temperatura ambiente”, Arcetri Technical Report 9/2012
RD11	Oliva et al. 2009, “Specifiche per il PLC di controllo di GIANO”, version 13, 5 june 2009

Acronyms

GIANO	Name of the instrument (not an acronym)
GN2	Gaseous Nitrogen
LN2	Liquid Nitrogen
NIR	Near InfraRed
PLC	Programmable Logic Computer
PT100	Platinum Thermo-resistor with 100 Ohm at 0 °C
TBC	To Be Confirmed
TBD	To Be Defined

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1 Scope

This document describes the operations necessary for the GIANO instrument and its relative control systems. **WARNING:** this document is intended only for the use of specialized persons with specific knowledge of the instrument. In particular, it includes the description of operations which may be potentially dangerous for people and for the instrument itself.

The common-user operations, necessary for the day-to-day use of GIANO, are the subject of a TBD document to be prepared by a TBD staff member of the TNG in charge of the common-user interface for GIANO. An experimental version of such an interface, developed for the laboratory in Arcetri (see RD7), may be used as starting point.

2 The vacuum chamber and the cryostat

A detailed description of the instrument is given in RD1 to RD4. For the purpose of this document we summarize that the GIANO spectrometer is mounted on a rigid aluminum bench thermally connected to a LN2 tank. Following the ray-path from the entrance window, the spectrometer includes a flat window, a cold stop, a filters wheel, a slit, the spectrometer optics (7 mirrors, 3 prisms, 1 grating) and a $2k^2$ HgCdTe detector array. All these elements are included inside a vacuum chamber which is permanently connected to all the sub-systems (pipelines, valves, pumps, sensors, PLC) necessary to create, maintain, monitor and control the vacuum and the cryogenic status of the spectrometer. All the operations are performed and supervised by the PLC (see RD11). The PLC is controlled through a dedicated panel (see Sect. 3).

The fundamental requirements for the functioning of the spectrometer are summarized in the compliance matrixes reported in RD4. We replicate here (table 2.1) the information relative to the interfacing to the TNG, which were updated after the Jul 2012 and Jul 2013 commissioning runs.

Table 2.1 Characteristics, performances and compliance matrix for the TNG interface

Parameter	Requirement	Actual	Comment
Instrument positioning	Nas-A room	Nas-A room	Compliant.
Light pick-up	OIG focus, via fibers	OIG focus, via fibers	Compliant.
Acquisition and guiding	NIR camera in pre-slit module + SARG-like guider-interface	NIR camera in pre-slit module + SARG-like guider-interface	Compliant
Electric Power UPS	380V, 6 kW 220V, 1 kW	380V, 6 kW 220V, 1 kW	Compliant
Compressed-air	1 line >6 bar Dry air	1 line >6 bar Dry air	The PLC goes into an alarm state, which blocks all operations, as soon as the air pressure drops. The same alarm occurs if the air-filter of GIANO is full of water.
Gas exhaust	2 lines	2 lines	1 line for exhaust (oil contaminated) fumes of rotary pump. 1 line for out-boiling GN2.
LN2 supply for normal operations	30 liters/day	30 liters/day	The LN2 must be in a pressurized (0.5 bar) tank connected to the cryostat.
LN2 supply for cooling down	800 liters in 3 days	800 liters in 3 days	The LN2 must be in a pressurized (0.5 bar) tank connected to the cryostat.

The spare parts of the custom spectrometer includes a window, slits, filters, flat mirrors, grating, cryogenic motors, temperature sensors. The vacuum-cryogenic part is made by off-the-shell components which can be purchased directly from the manufacturers.

2.1 Safety of the cryo-vacuum system

The only truly dangerous occurrence is a loss of vacuum (i.e. a gas-leak sufficient to increase the pressure above 10^{-2} mbar) when the cryostat is cold. This would cause the formation of ice outside and inside of the whole spectrometer. It could irreparably damage the optical components and/or the detector. Luckily, this problem is virtually impossible to occur, because the vacuum system is sturdy and well proofed. It can maintain a good level of vacuum for many months, even when subject to mechanical disturbances, as it occurred when it was shipped to the TNG.

Such a disaster can only be produced by manually opening one the three valves which can let air into the cryostat. The first is the large gate-valve for the cold-trap, on the right-hand side of GIANO. This valve is marked with a warning sign and is blocked by a mechanical system which requires a special tool for opening. The second valve, on the left-hand, back-side of GIANO, is marked with a warning sign and blocked by two mechanical systems which require special tools for dismounting. The third is a small needle-valve on the side of the turbo pump, in a hardly accessible position below the vacuum chamber. This valve will be mechanically protected or removed by F. Ghinassi.

2.2 Risks related with LN2 refilling and cooling down

The cooling down and refilling of LN2 is under the supervision of the PLC. The operations are performed using the “Level panel” (see Sect. 3.4). Besides the common dangers associated to the use of cryogenic liquids (e.g. skin-burns), the only risk for the instrument is that of a “forced thermal-cycle”, with consequent loss of scientific operations for about 5-6 weeks. This could occur if somebody forgets to refill - or replace - the external LN2 reservoir. In such a situation, the tank will only receive compressed air, instead of LN2, from the external reservoir. If humidity and other impurities are present in the compressed gas, they could form a frozen cup which blocks the LN2 pipelines inside the cryostat. Once this cup has formed, it becomes impossible to refill LN2 into the cryostat. One must wait until the instrument has warmed-up and the frozen cup has dissolved.

2.3 Risks related to heaters

The instrument also includes heaters and a cold-trap, which could be used to perform a fast (3-4 days) warm-up during special maintenance, under the direct control of the manufacturers. The cold-trap is normally dismounted, and it cannot be mounted while the instrument is cold. Consequently, the heaters must not be used in normal situation. The risk of using the heaters without cold-trap is a contamination of the spectrometer optics by the hydrocarbons produced by the out-gassing of the heaters. To avoid this risk we physically disconnected the fuses (4FU1) on the power supply line of the PLC.

2.4 Secondary control systems of the instrument

In parallel with the industrial control system, GIANO includes three custom control systems, which were developed in Arcetri. The first is in the small box attached in front of GIANO. It is used for the detector read-out. The second is in the large electronics rack on the right-hand side of GIANO. It provides the power to the detector control system and it supervises the temperature sensors and the cryogenic motor drivers. The third is in the large electronics rack, on the left-hand side of GIANO. It supervises the mechanisms in the pre-slit slit system, including the calibration box. This last part was first delivered in July 2013 and completed in Oct 2013. The spare parts include a complete copy of the detector-control electronics (see RD9, RD10, RD11), one replacement for the embedded PC and of the control board for the second control system, and one U-Ne calibration lamp.

To simplify the powering and reset operations of the secondary control systems, it is convenient to plug the large electronics racks into power sockets which are remotely controlled by the TNG control system.

3 PLC and PLC control-panel

The PLC of GIANO is a commercial system whose hardware and software are made according to industrial standards. One of its fundamental characteristics is to protect the cryo-vacuum system against any foreseeable problem. To this purpose, whenever a power failure or a major alarm occurs, the PLC locks all the gate valves and stops any on-going operation. In such a condition (“safe-state”), the cryo-vacuum system is safe, but cannot be refilled with LN₂. The alarms set by PLC can be reset directly accessing the PLC control-panel (suitable only for “super-users”), or remotely, via a TBD common-user interface (see Sect. 1) which communicates with PLC via its dedicated serial (MODBUS) protocol. In the following we describe the operations which can be performed using the PLC panel.

3.1 Power on/off , emergency button and alarms

The emergency button forces the PLC into safe-state. The same effect is achieved by turning the PLC off. At power on, the PLC is always in an alarm status equivalent to that set by the emergency button. The reset to normal status is achieved by pressing the square reset-key below the panel.

Other alarms can only be reset through the “Alarm panel” (see Sect. 3.7). Powering the PLC off does not reset the alarm status.

3.2 Vacuum panel

This panel includes the commands and parameters relative to the vacuum pumps. The main panel (Fig. 3.2.1) shows the pressure inside the cryostat (PT-202) and allows one to start or stop the pumps. All the commands to the pumps, valves and relative interlocks are directly handled by the PLC. After a pumps-stop (or an alarm), the cooling of the turbo pump remains active for ~15 minutes, while the start-key remains non-active. This delay time cannot be modified.

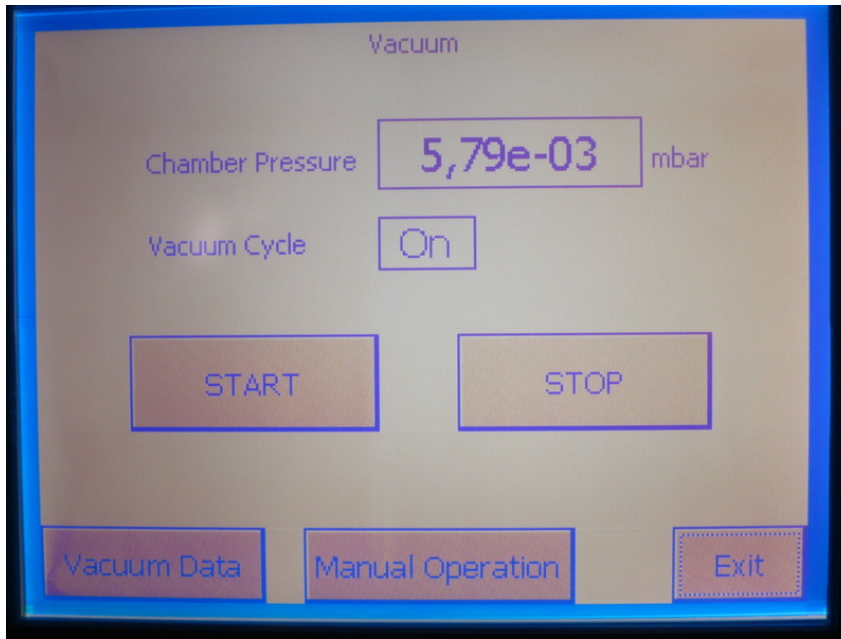


Figure 3.2.1 Vacuum panel

The “Vacuum Data” panel (Fig. 3.2.2) shows the following information

PT-201	Absolute gas pressure at the rotary pump
PT-202	Absolute gas pressure inside the chamber
YY-201	Status of the gate-valve between rotary and turbo pump
YY-202	Status of the gate-valve between the turbo pump and the vacuum chamber
P-201	Status of the rotary pump
P-202	Status of the turbo pump
FLCEMER	Flag for auto-pump-on in case of abnormal pressure in vacuum chamber
PCEMER	Threshold for abnormal pressure in vacuum chamber

The last two parameters can be modified by the user. They are used to setup an extra-safety operation, which automatically switches the pumps on whenever the instrument is cold and the pressure of the vacuum chamber goes above a given threshold. A typical value for PCEMER is 5E-5, values lower than 1E-5 are not recommended. *WARNING:* when this safety operation is activated, the PLC stops the automatic LN2 refill (flag FLN2C, see Sect. 3.4).

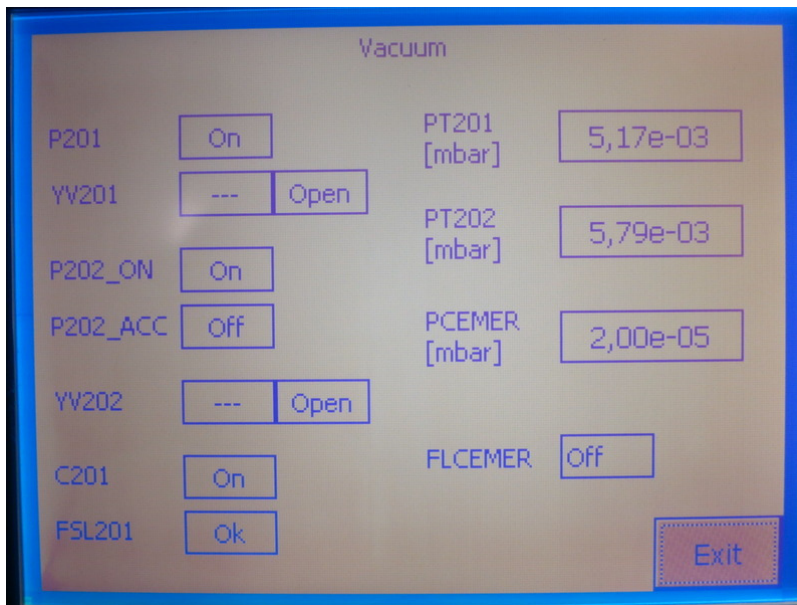


Figure 3.2.2 Vacuum data panel

The panel “Manual Operation” must not be used. It is only intended for special maintenance operations under the direct control of the manufacturers.

3.3 Pressure panel

This panel is used to monitor and control the pressure of the out-boiling LN2 inside the tank. The main panel (Fig. 3.3.1) shows the absolute pressure of the tank and allows one to start/stop the automatic control of the pressure.

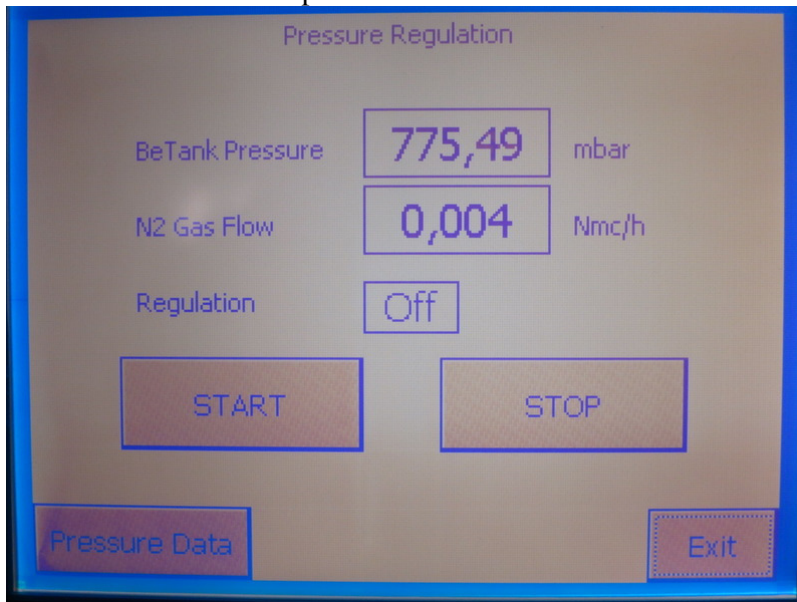


Figure 3.3.1 Pressure panel

The “Pressure Data” panel, shown in Fig. 3.3.2, includes extra information and allows one to modify the set-point value of the pressure (SET_PT101), the flag that activate the PID control (PAUTO) and the parameters of the PID control. The value of PT101_SET must be about 10 mbar above the yearly maximum value of ambient pressure. The PAUTO flag must be On. The PID parameters must not be modified, i.e. they must be PIG_G=12.0, PID_TI=1.20, PID_TD=0.00.

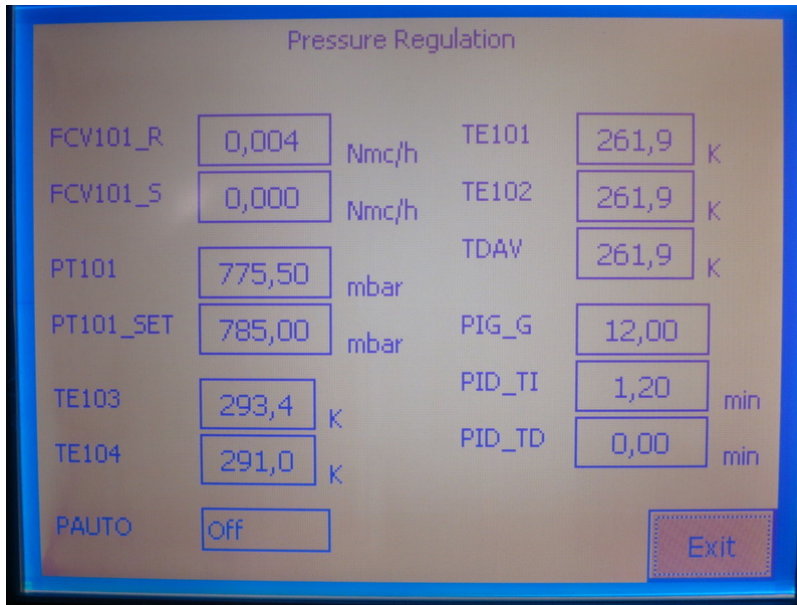


Figure 3.3.2 Pressure Data panel

3.4 Level panel

This panel is used to monitor the level of LN2 and to control the cooling and LN2 re-filling system. The level of LN2 is given by the weight of the cryostat (WT-100), which is shown in the main panel (Fig. 3.4.1), minus the weight of the empty cryostat. The latter value must be manually recorded before cooling down the instrument. The tank capacity is about 70 kg, overflowing of LN2 is automatically handled by the PLC (alarms of TE103 and/or TE104, see Sect. 3.7).

The main panel also displays the cooling/heating rate (DTHR, in K/hr). This parameter, which is updated every 60 seconds, is used to monitor/control the cooling and heating operations. The upper-limit for this rate (absolute value) is defined by MAXDTHR. This parameter can be modified by the user (allowed range 0-99).

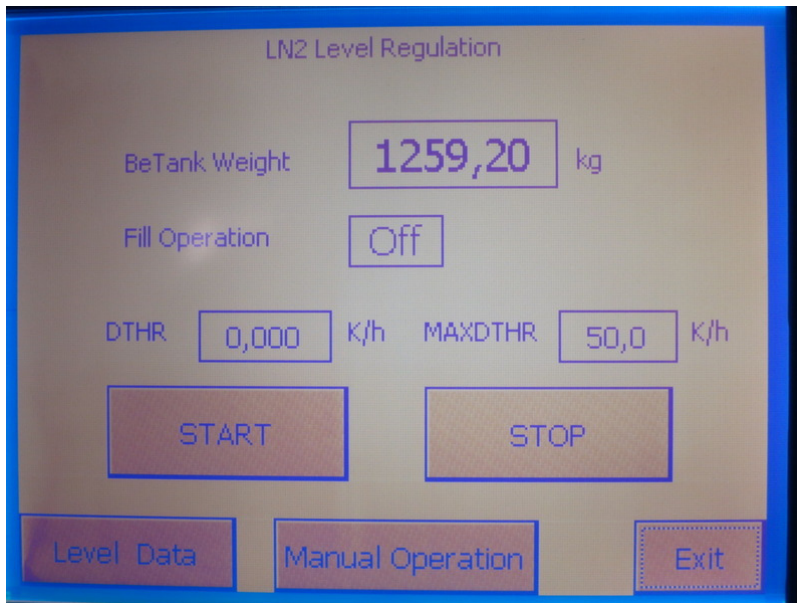


Figure 3.4.1 Level panel

The “Level Data” panel (Fig. 3.4.2) includes the following parameters, which can be modified by the user

MAPVLN2	Max. aperture (%) of LN2 valve when tank is warm, see Sect. 3.4.2
MAXVLN2	Max. aperture (%) of LN2 valve when tank is cold, typical value 100%
TDCRIT	Temperature below which the tank is cold, typical values 80-85 K
FLN2C	Automatic refill flag, must be set to 1 to activate auto-refill
WEIGHT_MIN	Min. weight of cryostat, auto-refill activates if WT-100<WEIGHT_MIN
WEIGHT_MAX	Max. weight of cryostat, auto-refill stops if WT-100>WEIGHT_MAX
DT_MAX	Max. time (seconds) from last LN2 refill, typical value 85000
TOPEN_MAX	Max. time (seconds) of LN2 refill, typical value 3000
TIMELN2V	Time (seconds) for cooling external LN2 tube, typical values 100-200
TUBLN2M	1 st parameter controlling by-pass valve on LN2 line, must always be = 0
TUBLDIS	2 nd parameter controlling by-pass valve on LN2 line, must always be = 1

The “Level Data” panel also includes the following information

LV101	Actual aperture of the LN2 valve (in %, i.e. from 0 to 100)
TE103	Temperature of output GN2 pipeline
WT100	Actual weight of the cryostat (kg)
YY102	Status of the by-pass valve on LN2 line

The screenshot shows a control panel titled "LN2 Level Regulation". It contains several input fields and status indicators arranged in two columns. The left column includes: LV101 (0 %), MAPVLN2 (40 %), MAXVLN2 (100 %), TDCRIT (85,0 K), YY102 (Close), TE103 (293,4 K), FLN2C (Off), and TUBLN2M (Off). The right column includes: WT100 (1259,20 kg), WEIGHT_MAX (1334,00 kg), WEIGHT_MIN (1290,00 kg), DT_MAX (85400 sec), TOPEN_MAX (3600 sec), TIMELN2V (30 sec), and TUBLN2DIS (On). An "Exit" button is located at the bottom right.

Figure 3.4.2 Level Data panel

The panel “Manual Operation” must not be used. It is only intended for special maintenance operations under the direct control of the manufacturers.

3.4.1 LN2 automatic refilling

This operation is activated by setting the FLN2C flag and manually starting the filling operation. The first phase, which lasts TIMELN2V seconds, is used to cool down the external LN2 tube. After this, LN2 flows into the pipeline feeding the LN2 tank inside the instrument. Under normal conditions, the filling continues until the weight of the cryostat (WT-100) reaches a user-defined maximum value (WEIGHT_MAX). Alternatively, the filling could stop after a given time-out (TOPEN_MAX); this normally means that the external LN2 tank is empty. The filling may also

stop because the tank is over-filled. In such a case the PLC goes into an alarm-status (see Sect. 3.7). When this occurs, it is necessary to decrease the value of WEIGHT_MAX.

3.4.2 Cooling the instrument

The cooling is a non-standard, complex and potentially risky operation. It requires the continuous presence and supervision of one or more persons with specific knowledge of the instrument. The risks related to the cryogenic system are those described in Sect. 2.2, and are particularly serious because the external LN2 tank can get empty in just a few hours. An additional risk is related to the cooling speed of the detector that, according to the manufacturer, must be <6 K/hr.

The fundamental parameters which control the cooling are MAPVLN2 and MAXDTHR. The first determines the flow of LN2 into the tank. Typical values for MAPVLN2 are 25-35%, but are difficult to predict because the flow-rate of LN2 also depends on other parameters, such as the pressure and the level of the external LN2 tank.

The value of MAXDTHR is used to avoid an exceedingly fast cooling rate. If the cooling rate (DTHR) becomes faster than MAXDTHR, the PLC progressively closes the LN2 valve. Once DTHR has dropped below MAXDTHR, the PLC progressively re-opens the LN2 valve. A safe value of MAXDTHR is 15 K/hr, larger values may result in a too fast cooling rate of the detector.

A typical problem one could encounter is a very irregular cooling rate, with long periods of low LN2 flow followed by sudden “gulps” and fast decreases of the temperature of the tank. This condition does not pose any risk on the system, as long as MAPVLN2 $<$ 35, MAXDTHR $<$ 15 and the pressure of the external LN2 tank is $<$ 0.5 bar. However, it may abnormally prolong the cooling procedure, and cause an excessive consumption of LN2. This may become particularly annoying if the cooling operation is interrupted for many hours, e.g. during the night. In such a situation one typically needs $>$ 3 days to cool the tank below 85K, temperature at which the LN2 can be safely stored inside the tank. Once this condition is reached, the cooling procedure becomes much easier, because it only requires re-filling the tank before it is gets empty again.

3.5 Cold trap panel

This panel is used to control the cold-trap, which is normally not-mounted. It is used only for special maintenance by the manufacturers (see Sect. 2.3).

3.6 Heaters panel

This panel is used to control the heaters inside the vacuum chamber. The heaters are physically disconnected. They can only be used in combination with the cold-trap (see Sect. 2.3).

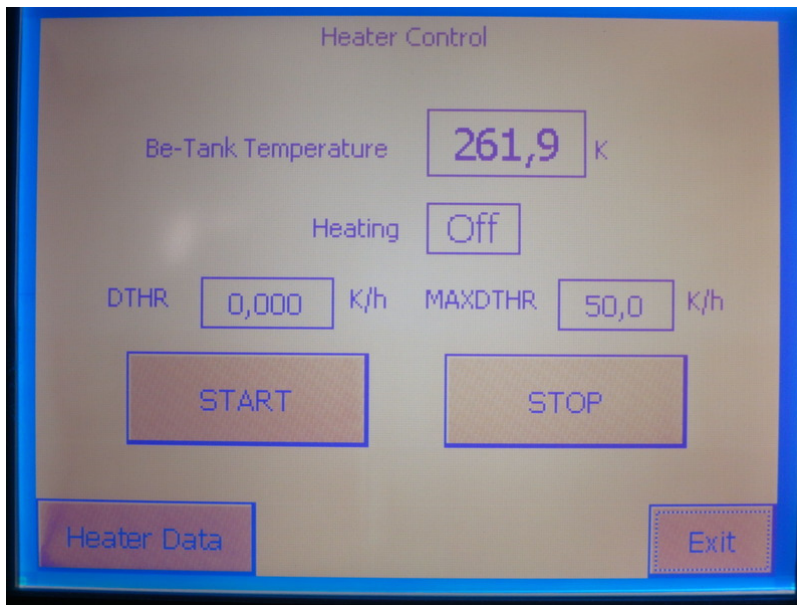


Figure 3.6.1 Heather panel

However, the panel “Heather Data” (Fig. 3.6.2) contains the following parameters which could be useful for normal operations

TE101	Temperature of LN2 tank as read by first PT100 sensor on tank
TE102	Temperature of LN2 tank as read by second PT100 sensor on tank
TDAV	Average temperature of LN2 tank (average between TE-101 and TE-102)
FTD1	On/off flag for TE-101 (can be set to off when PT100 sensor is damaged)
FTD2	On/off flag for TE-102 (can be set to off when PT100 sensor is damaged)
TE301	Ambient temperature as read by first PT100 sensor
TE302	Ambient temperature as read by second PT100 sensor
TAAV	Average ambient temperature (average between TE-301 and TE-302)
FTA1	On/off flag for TE-301 (can be set to off when PT100 sensor is damaged)
FTA2	On/off flag for TE-302 (can be set to off when PT100 sensor is damaged)

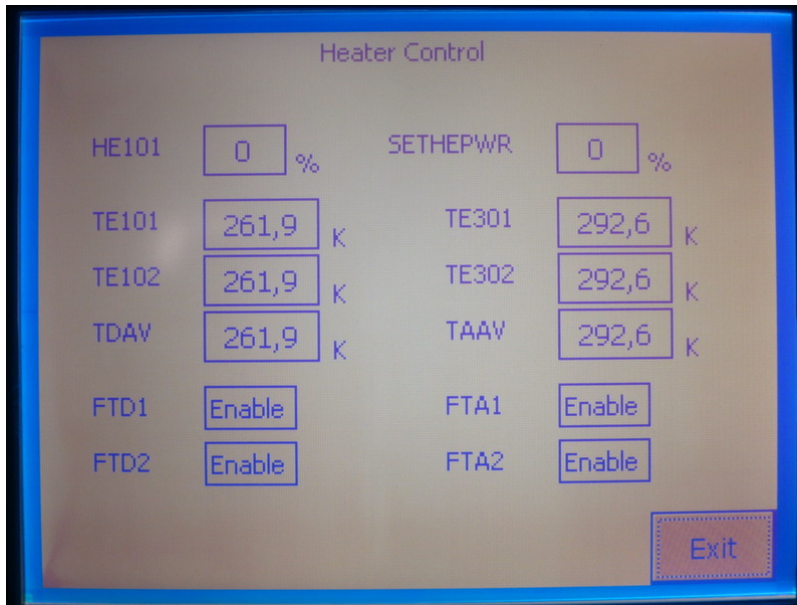


Figure 3.6.2 Heather Data panel

3.7 Alarms panel

This panel lists the status of all the alarm flags, and allows one to reset those which have been activated. The reset operation works only if the reason which caused the alarm has been resolved. Please note that a power-off of the PLC does not reset pending alarms (see Sect. 3.1). The tables 3.7.1, 3.7.2 and 3.7.3 list and describe of the alarms. Another list and description of all the PLC variables and alarms, as well as their byte-mapping for the MODBUS communication, is available in RD11.

Table 3.7.1 Common alarms, which can be normally recovered

PSL901	Pressure of compressed air too low or air-filter to be purged (the compressed air entrance is on the back, right-hand side)
TSL103	TE-103 too low (normally means overflow of LN2 during re-filling, just need to modify WEIGHT_MAX and wait for warming-up of GN2 pipeline)
TSL104	TE-104 too low (normally means overflow of LN2 during re-filling, just need to modify WEIGHT_MAX and wait for warming-up of GN2 pipeline)
C201	Cooling system of turbo pump did not start (check power switch on top of yellow box on the back)
FSL201	Cooling fluid does not flow to turbo pump (check level of glycol in yellow box on the back)
Em.	Interlock emergency button (check position of red emergency button of PLC)
TT401	Temperature sensor of cold trap (TE-401) not connected. This alarm disappears only when the cold-trap is mounted. It does not affect the PLC operations.

Table 3.7.2 Non-common alarms, which could be recovered without special maintenance

TSH-Q	Temperature of PLC electric board out of range
HE101	Fault of power supply to heaters (switch off heaters or re-install fuses for special use of heaters with cold-trap, see Sect. 2.3)
MAXTIME YV401	Cold trap did not reach the low temperature setup (check LN2 supply to cold-trap, modify maximum time of cold-trap filling)
TE101	Fault of TE101 (need modifying FTD1, see Sect. 3.6)
TE102	Fault of TE102 (need modifying FTD2, see Sect. 3.6)
DT101/2	Inconsistent values of TE101 and TE102 (need modifying FTD1/2, see Sect. 3.6)
TE301	Fault of TE301 (need modifying FTD1, see Sect. 3.6)
TE302	Fault of TE302 (need modifying FTD2, see Sect. 3.6)
DT301/2	Inconsistent values of TE201 and TE302 (need modifying FTD1/2, see Sect. 3.6)

Table 3.7.3 Alarms that indicate hardware failures requiring special maintenance

P201	Fault of rotary pump
P202	Fault of turbo pump
YY201	Fault of gate valve on rotary pump
YY202	Fault of gate valve on turbo pump
Seq.Vac	Error in automatic sequence of vacuum pumps
PT101	Fault of pressure sensor of LN2 tank
PT201	Fault of pressure sensor of rotary pump
PT202	Fault of pressure sensor of cryostat
FCV101	Fault of mass flow control system on GN2 line
WT100	Fault of weight sensors
TE103	Fault of PT100 sensor on GN2 line
TE104	Fault of PT100 sensor close to mass flow control system



Figure 3.7.1 Alarms panel, first page

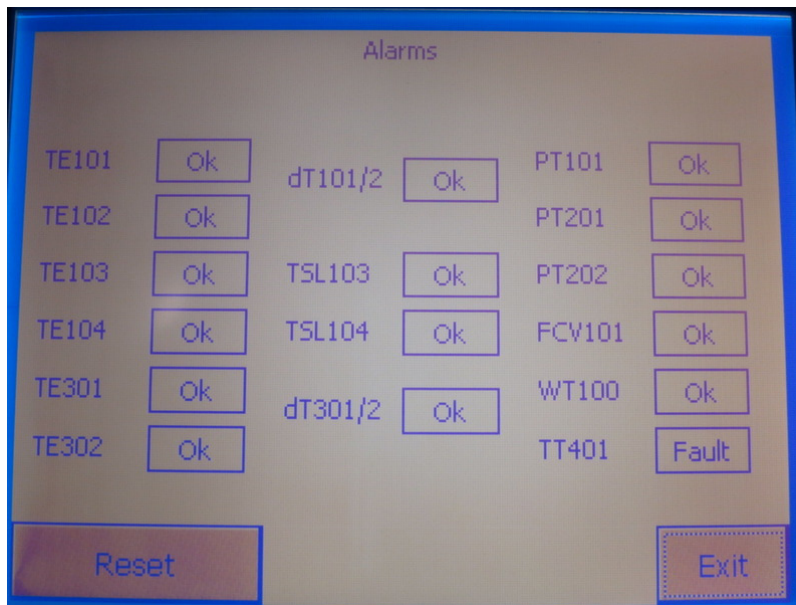


Figure 3.7.2 Alarms panel, second page

3.8 Setting panel

This panel can be used to modify the contrast and the sensitivity of the touch-screen. The other options must not be used.

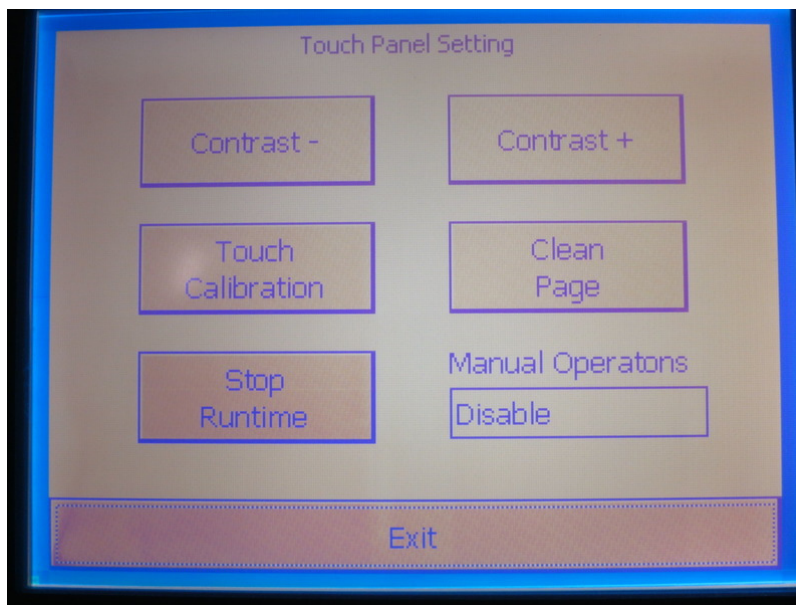


Figure 3.8.1 Setting panel